



HEAT RECOVERY FROM MILK COOLING SYSTEMS

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Heat energy is removed from milk during cooling. The heat energy can be 'dumped' from an air-cooled condenser, or all/or part of it can be transferred to water using a water-cooled condensing mechanism or a milk precooler.

Water-cooled condensers and milk precoolers will reduce compressor running time. However, the greater energy (and dollar) savings usually come from displacing water heating energy costs.

On most dairy farms the milk heat available can preheat more water than is required for normal wash-up and sanitizing. The problem then is one of choosing a 'heat recovery system' that will provide only the warmed water needed on an individual farm — with a reasonable payback.

MILK COOLING

To maintain milk quality, milk must be cooled from about 39°C (cow body temperature) to 3°C for safe storage. Milk is normally cooled by a refrigeration unit acting as a heat pump

— moving heat from a source (the milk) to a sink (air or water) using a carrier called a refrigerant (Freon gas).

When the refrigerant changes state from a liquid to a gas in the evaporator (bulk milk tank) it absorbs heat from the milk. The compressor pressurizes the gaseous refrigerant. Under pressure the hot refrigerant will give up heat and revert to a liquid. The condenser provides a means for this heat to be removed. The heat can be released to the air within the milkhouse (or directed outside) or can be re-used to water depending on the type of condenser in place. The liquefied refrigerant then passes through an expansion valve mechanism causing a pressure drop. The refrigerant is now ready to absorb heat again.

HEAT RECOVERY

Heat recovery systems do not change the basic refrigeration cycle. They simply change the type or combination of condenser(s) used to remove heat from the refrigerant.

Water-cooled condenser units can put all the heat from the refrigerant, which will include some of the compressor input energy, into water. This type of unit is efficient and generates about one litre of preheated water for every litre of milk cooled. This is often a much greater quantity of water than can be used effectively for normal wash-up and sanitizing operations in the milking area.

WATER TEMPERATURE

The average preheated water temperature from a water-cooled condensing mechanism is likely to be in the 50° to 60°C range. Starting water temperatures for milking equipment washing (sanitizing) should be 75°C. Thus all preheated water used for sanitizing must be further heated using conventional energy sources. However, many auxiliary water uses such as: cow prepping, calf feeding, employee showering, can use the preheated water without further heating.

PREHEATED WATER USAGE

Before investing in any type of heat recovery equipment, potential preheated water usage should be estimated. Dumping preheated water as a means of heat disposal may not be prudent — especially if potable water supply is limited.

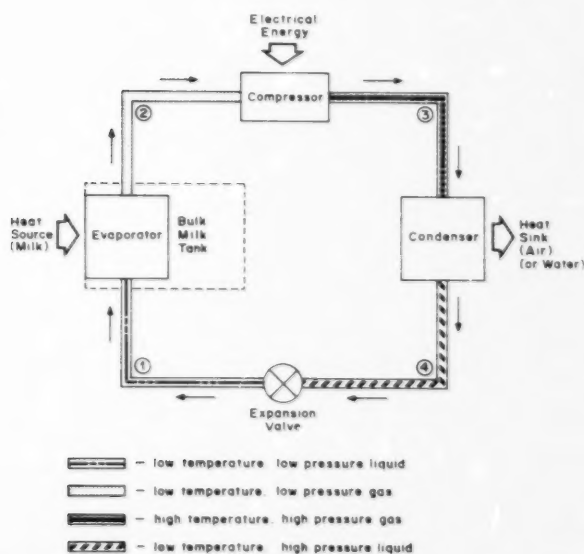


Figure 1: Refrigeration unit schematic

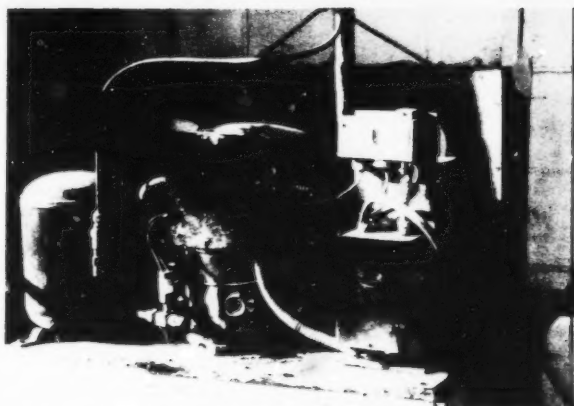


Figure 2: A conventional air-cooled condensing unit and compressor discharging milk heat into air.

Unfortunately no reliable warm (hot) water use guidelines are available. Reported average uses vary from 4 to 14 L/cow per day, with most below 10.

Except when significant warm water uses exist in addition to the normal equipment/facilities wash-up (sanitizing), it is not likely that more than one-half of the milk heat can be used effectively for water preheating. Fortunately equipment is available to permit recovery of one-half or less of the milk heat efficiently. The equipment choice will vary with the size of the refrigeration system required or in place for the specific dairy operation.

Milk heat is a reliable source, occurring every time the cows are milked. It must be used as produced or stored temporarily because the milk must be cooled quickly to maintain quality standards. Thus it is not a constant source for space heating (i.e. the calf nursery) and is not required on a year round basis for that type of application.

Pit floor heating with warmed water can also be installed in new milking parlors. If automatic prep stalls are used with parlors, the warmed water use rate might warrant total milk heat recovery.

No common external uses are evident or economically viable at this time for most Ontario dairy operations. If energy prices increase significantly, the possibility exists to pipe preheated water to the hot water heater in the residence. Warming the swimming pool is another potential use — but it is limited to very large milking herds.

ESTIMATING PRESENT HOT WATER USAGE

By accurately estimating the quantity of hot (75° to 77°C) or warmed (50° to 60°C) water that can be used effectively, local dairy equipment suppliers should be able to recommend the most cost effective heat recovery system for individual dairy operations.

If a conventional water heater is in place, a water meter in the cold supply line is the most accurate rate test.

For existing electric water heaters two other estimating techniques are available. One is to install a temporary kilowatt-hour meter. Energy consumption should be recorded for at least two and preferably about ten days. For heaters in cold

locations providing 75 to 77°C water assume about 10L of hot water for each kWh of energy input. Example: The electric water heater uses 360 kWh over 12 days. Average energy use rate will be 30 kWh/day. Approximate hot water usage is: $30 \times 10 = 300 \text{ L/day}$.

If a kilowatt-hour meter is not available, a recording amp-meter or a cumulative timer attached to the water heater circuit can provide average daily water heater 'on-time'. After checking the heating element rating, Table 1 can be used to estimate the hot water use rate.

Table 1 Approximate Daily Hot (75 to 77°C) Water Output from Electric Water Heaters in Cold Locations

Heating element ratings** -Watts-	Water heater 'On Time' – Average hours/day				
	4	6	8	10	12
	Approximate Hot Water Use – L/day*				
3000 (40 gal)	120	180	240	300	360
3800 (40 gal)	150	230	300	380	460
4500 (60 gal)	180	270	360	450	540

* Based on 10L/kWh which assumes a standby heat loss of approx. 33%. If testing occurs during hot weather the hot water use values can be increased by 10 to 15%.

** Based on both upper and lower elements being the same wattage with only one energized — which is the common arrangement in all newer electric water heaters.

HEAT RECOVERY SYSTEMS

1. Total water-cooled condensing systems put all of milk heat into preheating water. When used for total cooling more warmed water is produced than can be used in most dairy operations — unless employee showering or similar uses are evident. Most of these systems incorporates at least one large (450 L) uninsulated tank which permits radiant and convective heat losses between milkings. The tank(s) will also be

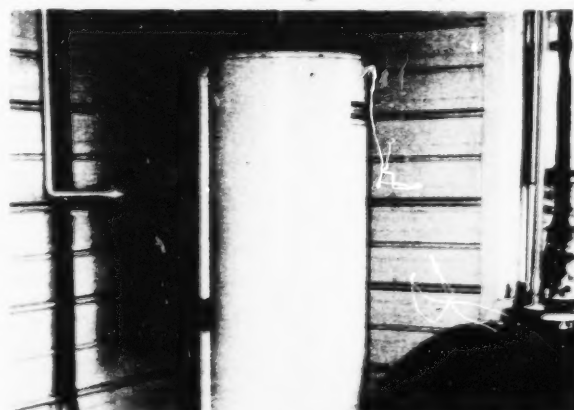


Figure 3: A complete water-cooled condensing unit putting the milk heat into water in the large vertical tank. A conventional water heater for 'topping up' is located in the adjacent service room.

equipped with a temperature sensitive relief valve to dump warmed water when the tank becomes full of warm water.

For larger bulk tanks having two refrigeration systems, one having a water-cooled condenser will supply the often desired 50% of milk heat for preheating water. The second one can be a conventional air-cooled unit providing desired milk room/parlor heating directly during the colder winter months.

2. Add-on recovery units can be connected to existing or new air-cooled systems. The units are often referred to as 'desuperheaters'. When connected into the refrigerant line between the compressor(s) and the air-cooled condenser(s), they utilize the 'superheat' of the compressed gaseous refrigerant. They effectively scalp heat and depend on the air-cooled condenser(s) to remove the residual heat from the refrigerant.

Add-on units have a fixed volume of water to preheat — commonly in the 190 to 450 L range. The tank can be an integral part of the desuperheater or separate — depending on the manufacturer. The integral units are insulated to minimize radiant heat losses as heat dumping is not required and the air-cooled condenser(s) will provide the desired space heating in cold weather.

Add-on desuperheaters can have refrigerant connections for one or two refrigeration systems. This makes this type of system very flexible in providing the quantity of preheated water than can be utilized and in permitting retrofit if needs change.



Figure 4: The add-on 'desuperheater' (right) with integral water storage supplies preheated water to the conventional water heater (left). Note the two refrigerant lines at top of 'desuperheater' unit.

Some add-on units have provision for 'topping up' the temperature of a portion of stored water volume for sanitizing purposes by including an electrical heating element. This feature can make a separate water heater unnecessary.

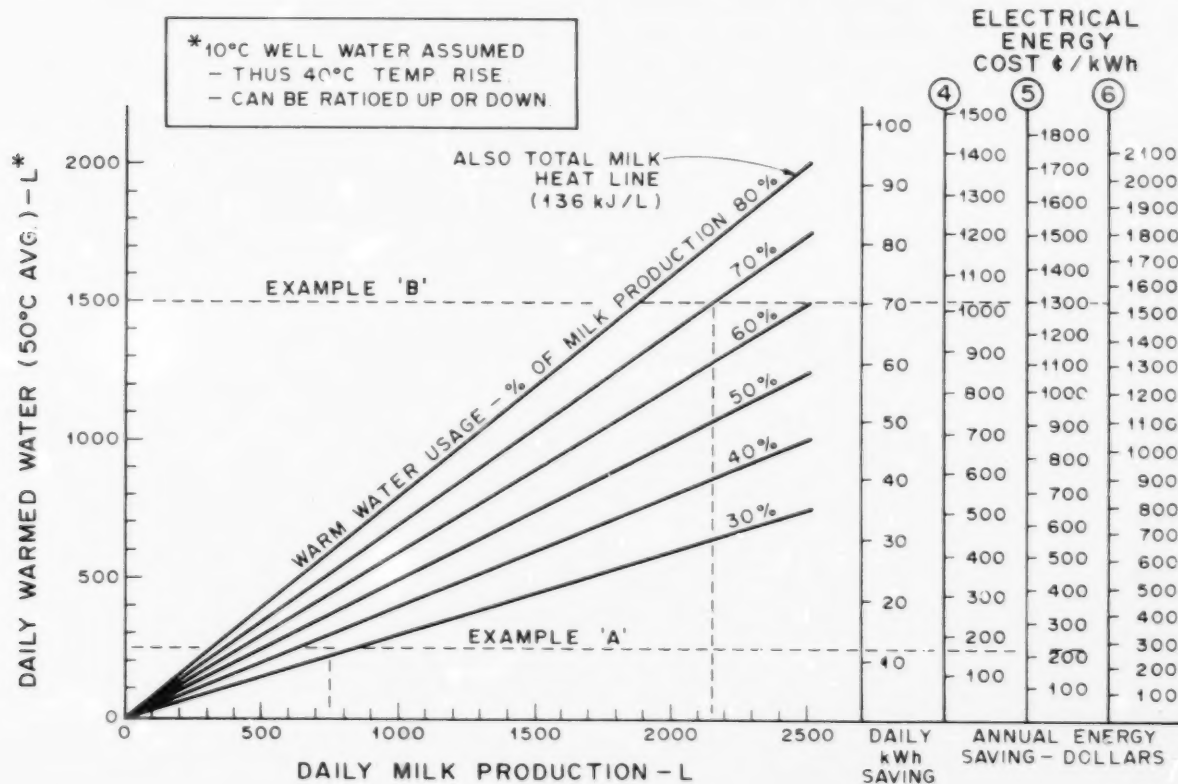


Figure 5: Potential energy (dollar) savings by transferring milk heat to water — based on daily milk production and warmed water usage.

3. Precoolers are an entirely different type of heat recovery system. They are not connected to the refrigeration system. They are heat exchangers which permit milk to be partially cooled by water prior to entering the bulk milk tank. The higher the cold incoming water flow rate the more effective the precooling of the milk. While the water to milk flow rate ratio can vary, the water must flow during the milking periods. For many dairy operations this tends to limit the potential uses of a relatively large volume of water especially when the common water to milk flow rate ratio is one or higher.

Precoolers may improve milk quality by reducing blend temperatures and/or milk cooling time if an existing refrigeration system is undersized/overloaded.

ECONOMICS

The economic attractiveness of heat recovery from milk must be based primarily on purchased energy displacement for water heating. While water-cooled condensers, desuperheaters and precoolers will reduce compressor running time, the resultant energy savings are not well documented.

Properly sized and well maintained conventional air-cooled condensers systems are generally doing an adequate job of lowering milk temperature quickly enough to maintain quality standards. However, when refrigeration system changes or upgrades are required heat recovery systems should be considered to reduce water heating costs.

Figure 5 illustrates by examples the range of opportunity for capital recovery of heat recovery equipment for most dairy operations in Ontario. Example "A" is for a common (35 milking cow) dairy unit producing 750 L of milk a day and using hot water at the rate of 250 L/d (7 L/cow/d). Only 33% of the milk heat can be used to preheat that amount of hot water. With electricity costing \$0.05/kWh as the water heating alternative energy the annual savings potential is \$210. The present cost for a small (190 L) add-on 'desuperheater' would be about \$1400. Thus the capital cost recovery is not particularly attractive at approximately seven years — simple payback without interest. The additional heating of all the water used for sanitizing in this example is approximately 50% of previous water heating costs.

In contrast, a much larger dairy operation, Example "B", producing 2150 L of milk a day and having a high percentage (70%) warm water to milk usage, has an excellent opportunity to benefit from milk heat recovery. With electrical water heating energy at \$0.05/kWh the annual savings potential is \$1300. This would permit an expenditure of \$3900 for heat

recovery equipment and provide simple payback in three years. A significant portion of the warmed (50°C) water could be used directly in this operation for showering, facility washdown etc.

SUMMARY

1. Heat recovery from milk by water-cooled condensing mechanisms is effective and provides a reliable source of heat for preheating water.
2. If more preheated or warmed water is produced than can be used effectively, energy savings should not be claimed for that portion.
3. Water heated to 50 or even 60°C is not hot enough for dairy equipment washing (sanitizing). The starting temperature should be 75°C.
4. The quantity of water held at 75°C should be kept to the minimum required for individual sanitizing events to minimize 'stand by' heat losses.
5. The water heater receiving water from a heat recovery system should be well insulated and located in a warm utility room if possible. A 24-hour time clock can be used on the water heater to control electrical demand and limit the time 75°C water is held. The water heater can be 'off-line' during milking period when demand peaks and 'on-line' two to three hours before line and/or tank wash. (Demand is only of concern to those paying a demand charge to the Utility.)
6. Pipeline and tank wash timer controls should be checked periodically to insure that excess quantities of hot water are not being used unnecessarily.

REFERENCES

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